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I, JONNE YABSLEY, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. 2002951351 for a patent by KEVIN STEPHEN DAVIES as filed on 12 September 2002.

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J R Yabsley

JONNE YABSLEY
TEAM LEADER EXAMINATION
SUPPORT AND SALES

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Simple Title

Ultra-reliable detection techniques using parallel wide beam optics

Detailed Title

Proximity detection device using a high speed camera with infinite focal length and very long depth of field.

Initial scope of this provisional patent

This provisional patent covers an invention that may be used in other situations and for uses other than safety but its initial design and marketing is for the protection of operators of brake presses (press brakes).

Overview

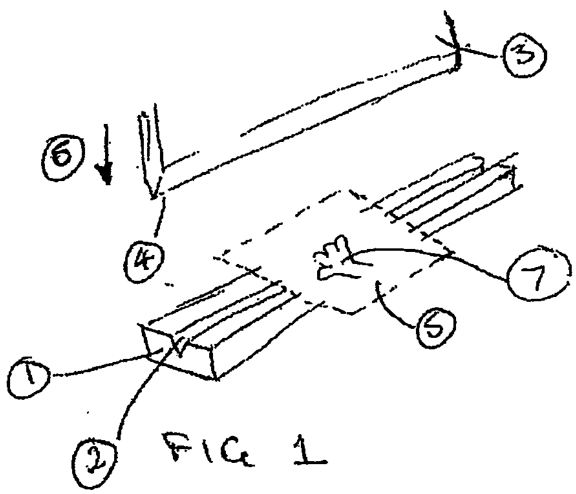

FIG 1

A typical break press has a long anvil (fig 1/1) with a VEE (fig 1/2) along the top and a long blade (fig 1/3) with a leading bottom edge (fig 1/4) that fits into the VEE of the anvil. To bend a piece of sheet metal (fig 1/5), the metal is placed across the VEE of the anvil. The operator then activates the break press, driving the blade down (fig 1/6) so it comes into contact with, and then bends the sheet metal that has been placed onto the VEE of the anvil.

This presents a danger to operators owing to their ability to inadvertently place their hands (fig 1/7) (or fingers) under the blade while it is driving towards the anvil. Clearly, the operator's fingers can be crushed between the blade and the sheet metal that is being bent.

Prior art

Many safety devices for this type of apparatus have been devised. The four main types will be discussed here:

Physical guarding

A mechanical guard is place between the blade and the operator making it difficult for the operator approach the blade.

This guarding technique is usually provided around the rear of press brakes but front guarding is not generally considered a realistic option.

Production complications associated with physical guarding are:

- Impeded operator access to the blade and anvil.
- Inefficient as the operator may need to remove the guards before being able to change blades or service the machine.
- The operator's vision is partially blocked as the guard obstructs the view of the material being bent.

Dangers associated with physical guarding are:

- Complete guarding is not possible as gaps must be left to allow for the sheet metal bending process.

The operator tether

This safety means physically forces the operator to stay clear of the machine while the bending process is in operation. This process may be either a 'double handed' start switch located a suitable distance from the blade or mechanical tethers, that limit the operator's access to the machine.

Production complications associated with operator tethers are:

- Inefficient as it may be difficult for the operator to hold the sheet metal appropriately while it is being bent.
- Inefficient as for a double handed start switch, the operator must repeatedly move both hands to the start switch instead of using a standard footswitch.
- If physically restrained then the operator may find it difficult to operate the machine efficiently.

Dangers associated with operator tethers are:

- Another operator may be called to help with production; in this case, the second operator is not protected.
- The sheet metal may not be supported correctly.

Light curtain

Multi-beam

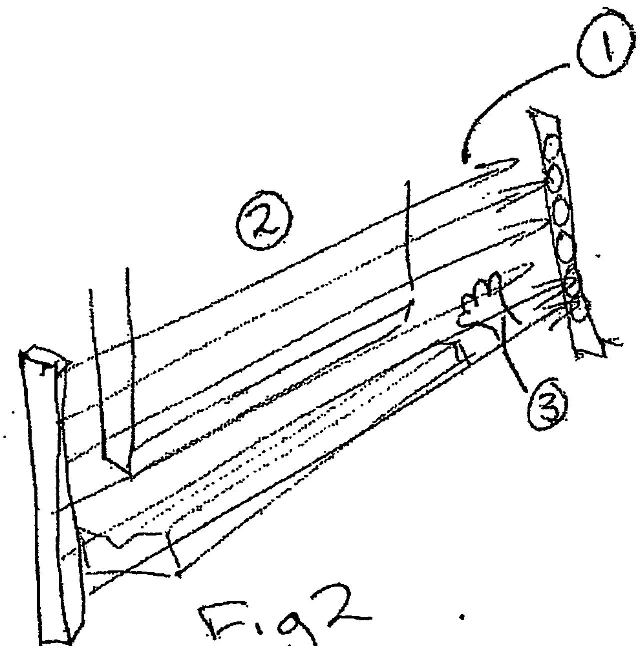

Fig 2

This involves a curtain of light (fig 2/1) in front of the blade (fig2/2). The curtain is made of many beams of light projected across the face of the blade. If the operator places a hand (fig 2/3) into these beams interrupting them then depending on which part of the beam is interrupted, (and with some designs, also depending on the position of the blade) the blade is either stopped until the operator confirms the curtain interruption or slowed to a safe speed.

Scanning or pulsed light curtain

Ref: US pat: 4127771 Date: 28/11/78 Company: SICK

This design is a little hard to understand, but to the best of the writer's understanding, this involves either a single scanned light or many pulsed lights in the curtain to allow the control unit to determine where the beam has been broken.

Production complications associated with light curtains are:

- Inefficient as the operator must reset the position of these light curtains before various production batches.
- Inefficient as the operator must repeatedly move the hands well out of the light curtain protection zone.
- Inefficient as the operator is kept away from the work area.

Dangers associated with light curtains are:

- Gaps in the curtain allow small objects like fingers to go undetected.
- Bending metal boxes makes gaps even more difficult to protect against.

Light beam on moving member

Ref: US pat: 5579884 Date: 03/12/96
Ref: Pat. WO 00/67932 – this patent discusses the inventiveness involved in the above patent

Method 1 - Spot laser or laser beams under blade

Ref: US pat: 6316763 Date: 13/11/01 – deals with ways for overcoming machine problems and laser vibration

Method 2 - Wide beam laser under blade

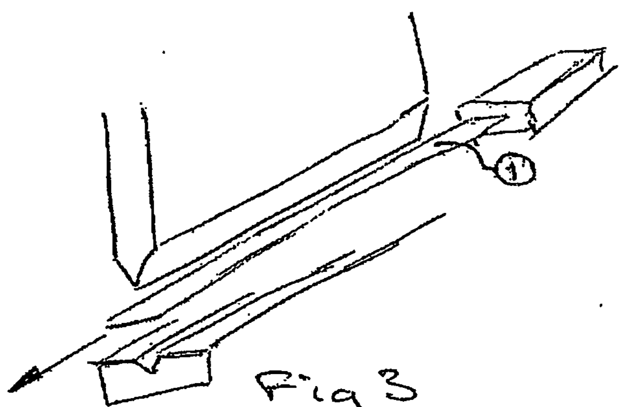

Fig 3

Ref: int. pat: WO 00/67932 Date: 16/11/00 – (fig 3/1)

Method 3 - Multiple spot lasers under blade

Ref: http://www.enutron.com/en00019.html *Date: 28/02/02* - (fig 4/1) – copied here for clarity

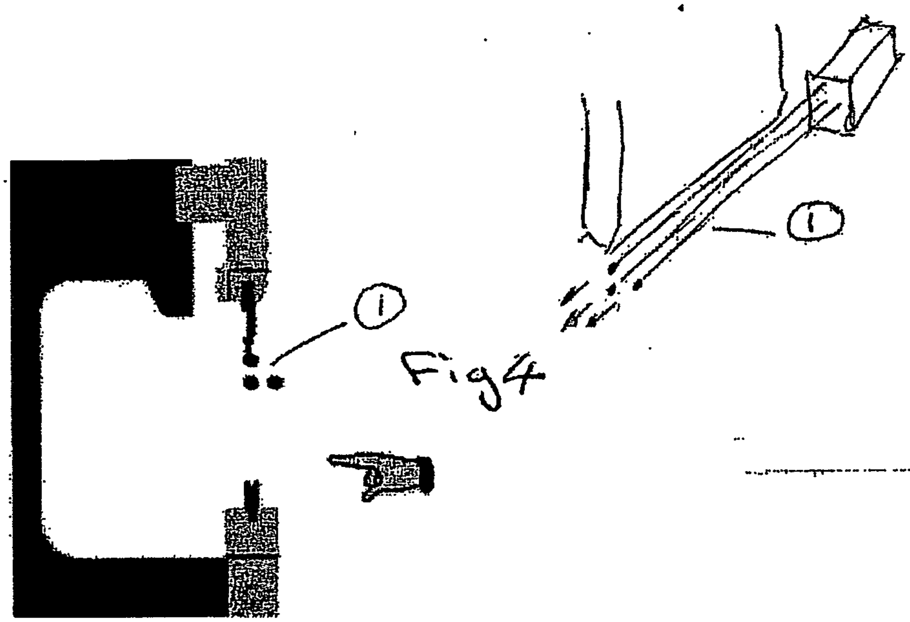

Fig4

Method 4 - Multiple wide beam lasers under blade

Ref: prov pat: PS1409 Date: 27/03/02

Description

Either a light beam or multiple light beams are projected along the leading edge of a blade. A controller is used to detect both the position of the blade and obstructions to the light beam. The light beam remains active while the blade is approaching the anvil and stays active until the light beam is too close to the anvil. When the controller determines that the light beam is about to be obstructed by the anvil or the material that is being pressed, the light beam is disabled. If the light beam is obstructed while it is active (above the anvil or material) then the press is stopped and the operator is required to confirm the obstruction before pressing continues.

For the designs using a single light beam, the beam must be placed far enough away from the blade so that when the beam is obstructed, the blade has time to stop before coming into contact with the obstruction.

As presses are designed to operate at higher speeds, the laser beam(s) must be placed at an ever increasing distances from the tip of the blade, this increased distance allows an obstruction to be detected and the blade time to stop before coming into contact with the obstruction. For very fast presses, this increased distance that the laser beam must be from the tip of the blade, exceeds a safe distance. This is because the laser beam is placed further from the tip of the blade than the width of an operator's finger.

For very fast presses, a multi laser system is used. The most common configuration for a multiple beams system is to place one beam close to the blade and a second beam far enough away to stop the blade before it comes into contact with the obstruction (fig 4/1). The closest beam protects against small obstructions close to the beam while the beam is operating at lower speeds, and the beam that is furthest from the blade is used for protection at higher speeds.

Production complications using light beams under blades are:

- Confirmation is required each time a new obstruction is encountered.
- Bent up stands when bending a box must be kept clear of certain areas in order to prevent false tripping of the safety system.
- System may require laser re-alignment when tools are changed.

Dangers using light beams under blades are:

- Entrapment where a finger is trapped by upstanding metal as a new bend is performed.
- Not safe if the operator doesn't adjust the laser to the correct distance from the blade.
- Not safe if the operator moves a hand into the danger zone just as the beams are disabled.

In certain modes, the rear area of the laser beam is disabled well above the anvil to allow for presses with a back gauge.

Other complications:

- These systems require a blade position sensing device (usually an opto encoder) as a second input to their controller.
- These systems have many unnecessary stops where the operator must confirm obstructions that are not dangerous.
- These systems do not guard against finger entrapment.
- These systems are based on optical lensing causing the protection zone to be relatively small.
- These system require confirmation of mute point and other operator actions when setting up the safety system for first use each day.

Many combinations of these guarding techniques have been used with one of the most common combinations being to guard other people from the rear of the press using physical guarding while using one of these four techniques to protect operators from the front of the press.

The inventor

The inventor has both a science and an engineering degree and has worked for about five years on press brake safety systems.

His first contribution is noted in provisional patent PCT/AU97/00005, where he added two parts to this patent, vibration correction by testing to ensure three lasers aligned at the same time and cross checking of the machine controller to ensure its mute point was set correctly.

His honours project for his engineering degree involved modulation techniques for projecting laser beams under a press blade and later he designed much of the Lazersafe safety system as described in international patent WO 00/67932.

This new invention draws on these past experiences with particular inspiration coming from the following:

- Previous design of much of the optical means for the Lazersafe controller - using this knowledge, the inventor has been able to visualise and develop a new large area parallel beam light emitting and receiving means.
- Use of an optical mouse - this gave the inventor the idea that CCD receivers (as in optical mice) were possibly suitable for this new device.
- Science degree - this permitted an understanding of the optical process involved in the existing Lazersafe transmitting means and so the ability to expand on this concept and invent a large area light emitting means. This also allowed the inventor to realise that the reverse process may be applied to a receiving means.
- Computer Science degree + Engineering degree - the ability to visualise methods for analysing the information received from a CCD camera to stop a press when an unsafe condition applies.

Prior work on hardware and software for the Lazersafe controller leading to an understanding of the problems and potential solutions that applies to safety devices for press brakes.

As co-inventor of the Lazersafe controller, the inventor of this new product has mentally pictured many new ways for improving the design and safety of press brake safety systems. Although many minor changes can be made to improve the existing designs, in the opinion of the inventor, the best solution lies in the development of the new invention specified below.

Design description

The preferred embodiment consists of the following:

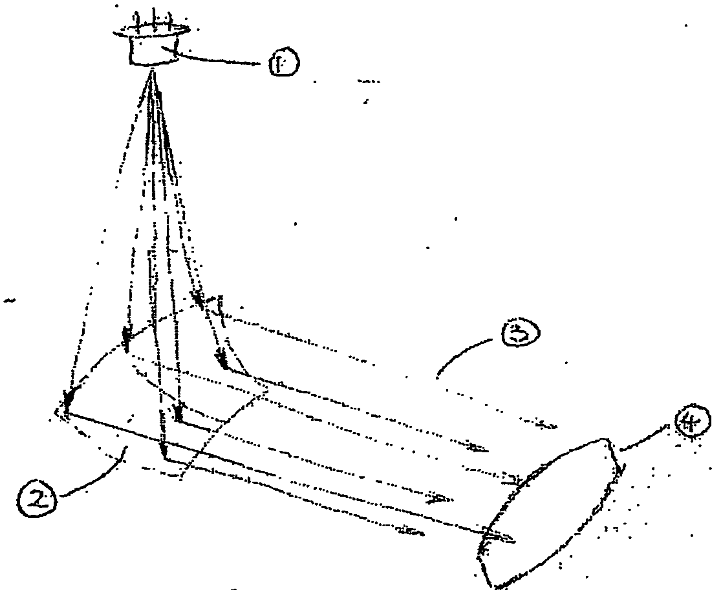

Fig 5.

A large area parallel ray light emitting means is used to illuminate the safety zone (fig 5/4) so that any objects illuminated by this light emitting means cast a shadow. The light emitting means is constructed as shown in fig 5. A laser diode (fig 5/1) projects its laser beam onto an off axis parabolic reflector (fig 5/2). [NOTE: The reflector can either be cast or manufactured from nickel using an electroforming process.] The reflector forms the light into a parallel beam (fig 5/3).

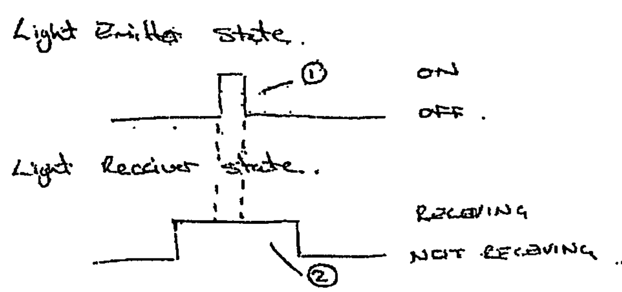

Fig6.

The laser diode is strobed (fig 6/1) much like a strobe light in a disco and timed to turn ON when the light receiving means is ready to receive light (fig 6/2). This strobing effectively results in the light receiving means detecting the equivalent of stop-motion-photography, thus reducing the blurring effect of fast motion.

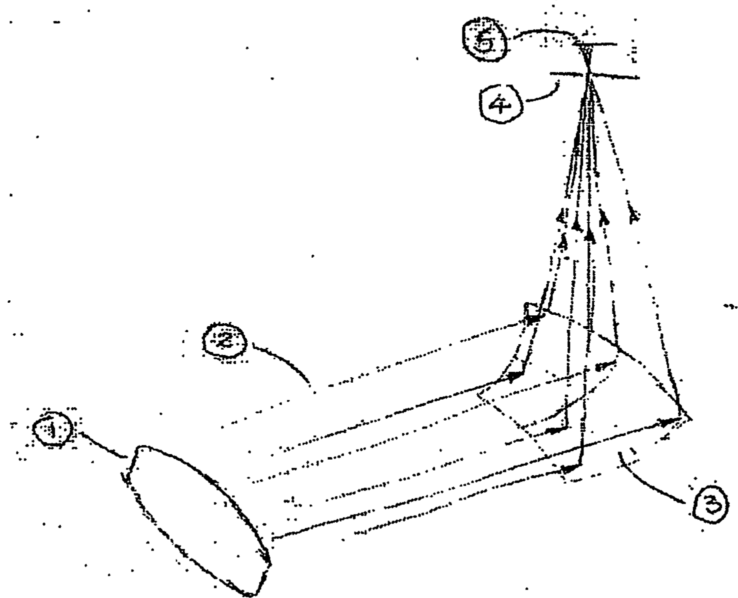

Fig 7

A large area parallel ray light receiving means is used to receive light from the safety zone so that any shadows cast by objects in the safety zone are detected. The light receiving means is constructed as shown in fig 7. A charge coupled device (fig 7/5) (CCD) is illuminated through a very small pinhole aperture (fig 7/4). Light passing through this aperture has been focussed by the off-axis parabolic reflector (fig 7/3). The focal length may be carefully adjusted to be very very sightly divergent. This divergence helps the control means to detect when the receiving means is not correctly aligned with the light emitting means – as this means one side of CCD will be illuminated with a sightly higher intensity than the other.

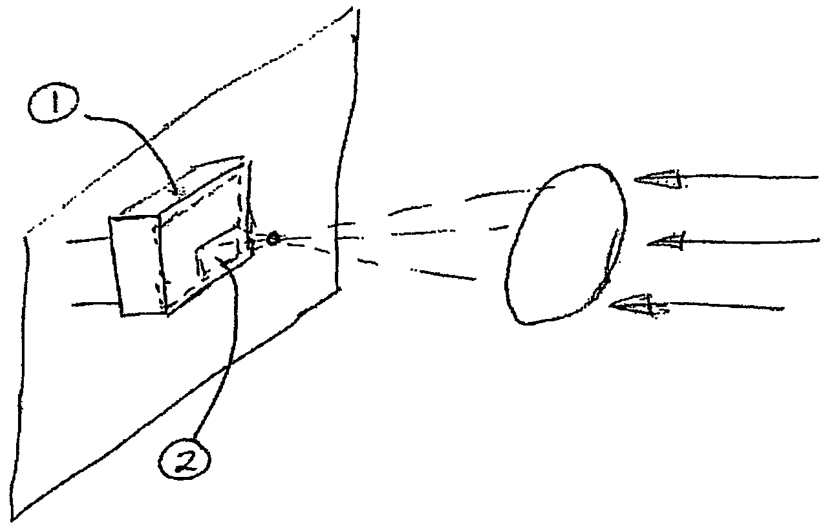

Fig 8.

The CCD (fig 8/1) is located so only part of it is illuminated (fig 8/2).

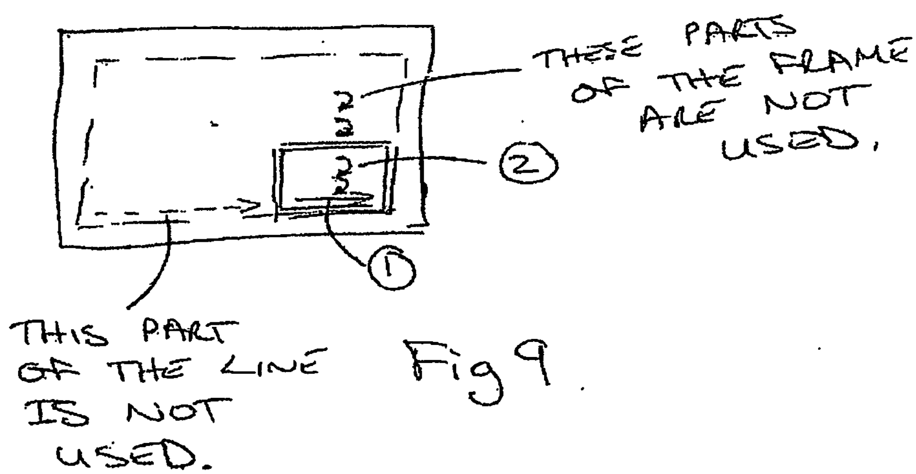

Fig 9.

This permits the device to output only part of each line (fig 9/1) and only part of each frame (fig 9/2). This results in much faster frame rates than would normally be expected from a standard CCD.

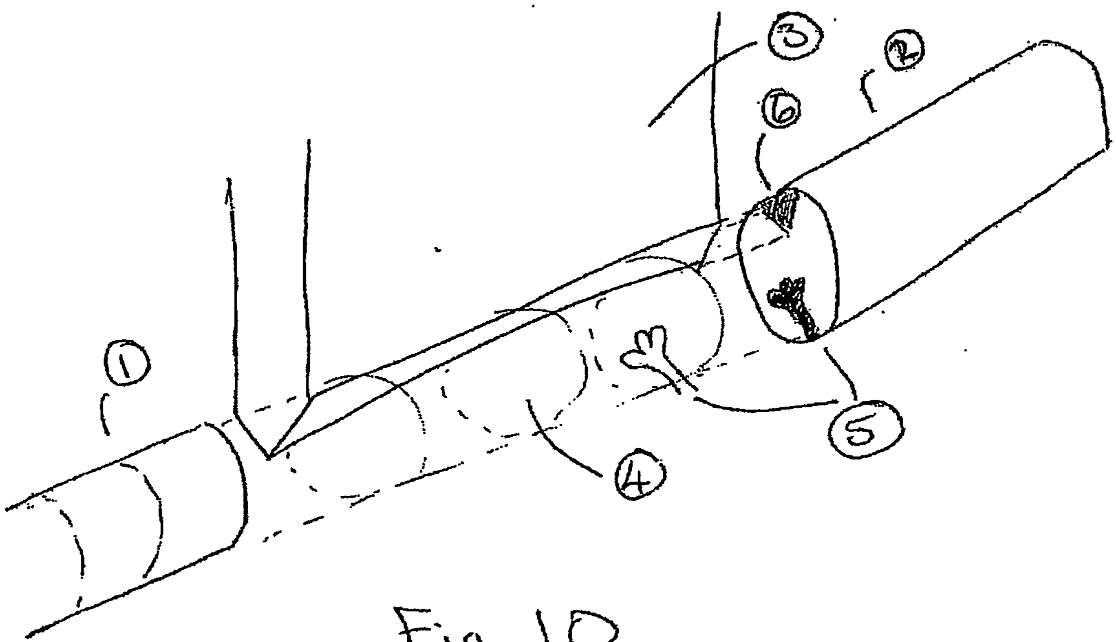

Fig 10.

Both light emitting (fig 10/1) and light receiving means (fig 10/2) are mounted at opposite ends of the blade of a break press machine (fig 10/3). The safety zone (fig 10/4) is the area between the light emitting and light receiving means where an object can cause a shadow (10/5) to be cast onto the receiving means. The safety zone is shown as being round here but it may be shaped differently due to the selection of light emitting devices and reflectors.

The light emitting means is aligned to shine along the blade so as to illuminate the light receiving means and the light receiving means is aligned along the blade so as to receive the light from the emitting means.

The emitting and receiving means are positioned at an appropriate height so the tip of the blade casts a shadow (fig 10/6) onto the active area of the light receiving means.

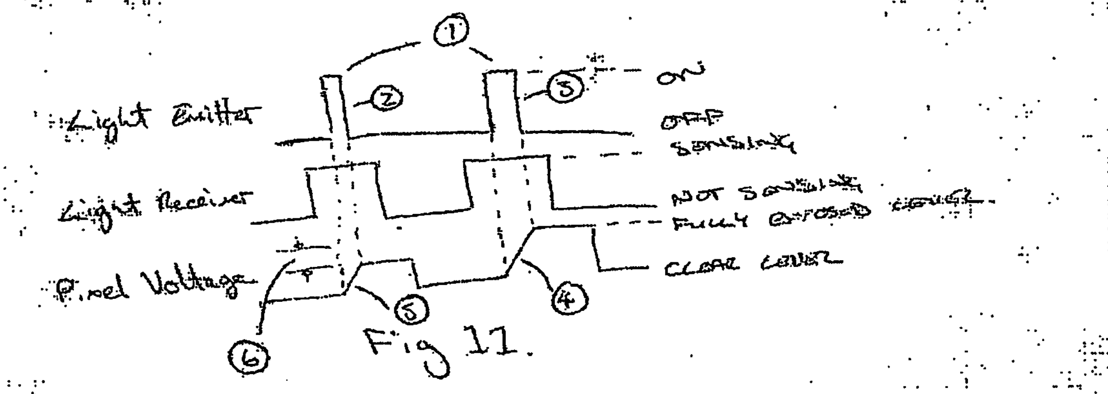

Fig 11.

The ON time of the light emitting means (fig 11/1) is modulated (fig 11/2 and 11/3). The causes the sense voltage on the exposed pixels of the CCD to modulate (fig 11/4 and 11/5) producing different intensity levels (fig 11/6) to be received with each image received onto the CCD. This modulation permits the control means to ensure ambient light interference can be detected and corrected for.

The light emitting means has a shadow mask built into it (fig 12/1). The is designed so it does not affect the overall sensitivity of the device.

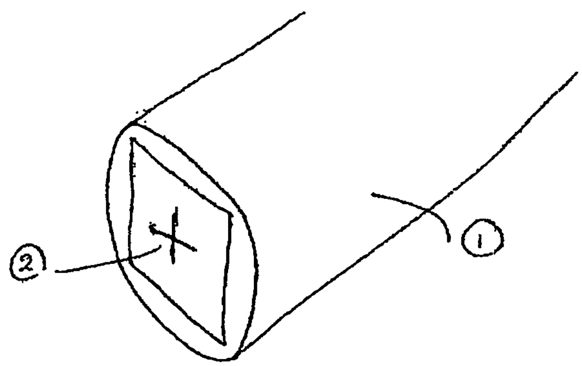

Fig 12.

By using this shadow mask, light emitting means misalignment is easily detected as the position of the shadow projected onto the receiving means moves laterally or vertically.

Light receiving means misalignment is easily detected as the received light intensity is brighter on one side of the detector (CCD) than the other.

Due to optical imperfections, light received at the receiving element varies in brightness across its field of view. These varying intensities may be used as the shadow mask.

The control means may use an optical encoder to determine the position of the blade.

The optical encoder reading is cross checked against the position of the anvil to ensure the light receiver, light emitter and optical encoder positions has not drifted.

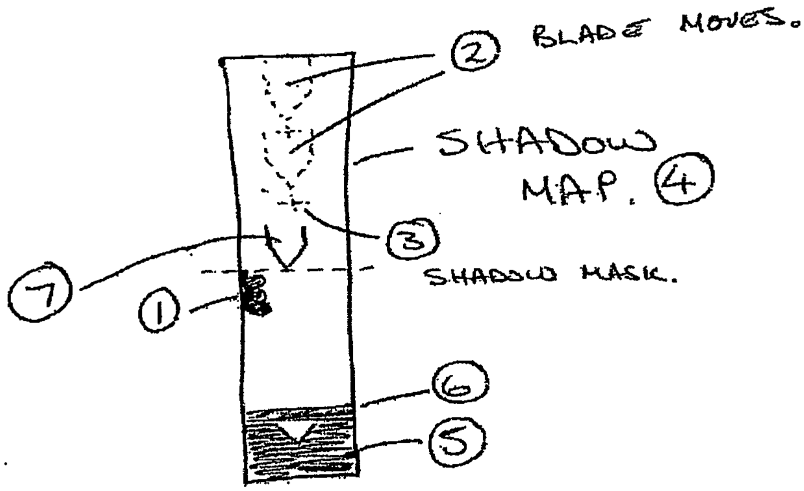

Fig 13.

Movement of the blade and hence the light emitting and receiving means form a moving map of shadows that are cast (fig 13/1). Use of the position detection means (optical encoder) along with these moving shadows permit the control means to create a map of shadows that are cast versus the position of the blade. This map will be called a SHADOW MAP for the purpose of this document. The SHADOW MAP covers the entire length of the approach of the blade.

The shadow formed by the tip of the blade (fig 13/2) is stationary with respect to the transmitting and receiving means so is not added to the SHADOW MAP. Likewise, the shadow formed by the shadow mask (fig 13/3) in front of the light emitting means is not added to the SHADOW MAP.

The shadow from the anvil (fig 13/5) and material (fig 13/6) are added to the SHADOW MAP on the first pass.

If a new shadow is detected (fig 13/1) that was not already in the SHADOW MAP (fig 13/4) then the press is stopped and the operator required to confirm the new shadow as being safe by simply continuing with the bending process. If the operator moves the obstruction before continuing, then the control means continues as if the obstruction had not occurred.

In order to help the operator identify the source of any new obstructions, after any new obstruction, the control means first slows the press and then stops it at a point where the blade is close to the obstruction (fig 13/7).

A picture of the obstruction may also be displayed on an operator's panel so the operator can more readily understand the cause of any obstructions.

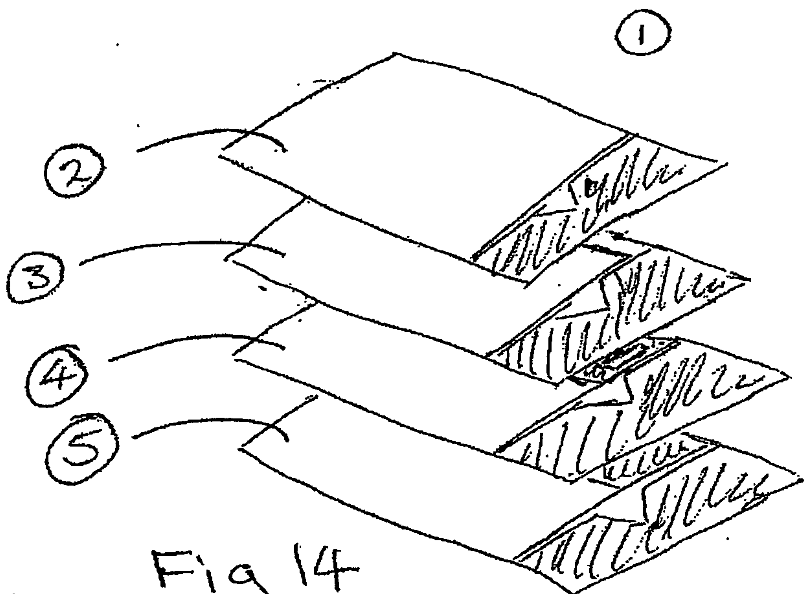

Fig 14

The control means keeps a SHADOW STACK (fig 14/1) of valid SHADOW MAPs so that the if the operator is say bending a box, then each of the arrangements involved in the bending of this box - say side 1 (fig 14/2), side 2 (fig 14/3), back (fig 14/4), front (fig 14/5) - are stored as independent SHADOW MAPs.

This means the controller only stops the press four times, for the first box that is bent. After this the shadow maps are in the memory stack and the press is no longer stopped for similar obstructions when bending subsequent boxes.

The controller does however stop the press at a safe point for each bend where due to obstructions from the material being bent, it cannot determine that it is safe to complete a bend in one operation. Determining safe operation is a heuristics bases operation, based on clearances, mechanical guarding at the rear of the press and the size and position of any obstructions (front of press, rear of press etc).

The controller forces the press to operate more slowly and / or inserts a blade stop close to the material if its field of view is sufficiently impeded so as to make it impossible to determine if a safe state exists.

The control means can also operate without an external blade position detector. This modification to the shadowmap process is shown below:

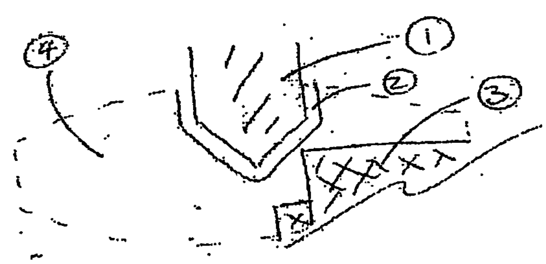

Fig 15.

The blade (fig 15/1) is illuminated by the light emitting means (fig 15/4). The control means creates a stop zone around the blade (fig 15/2). Any new obstruction (fig 15/3) – not already in the SHADOW STACK - that creates a shadow in this zone causes the control means to stop the blade and conditionally (as described previously) add this new entire image to the SHADOW STACK.

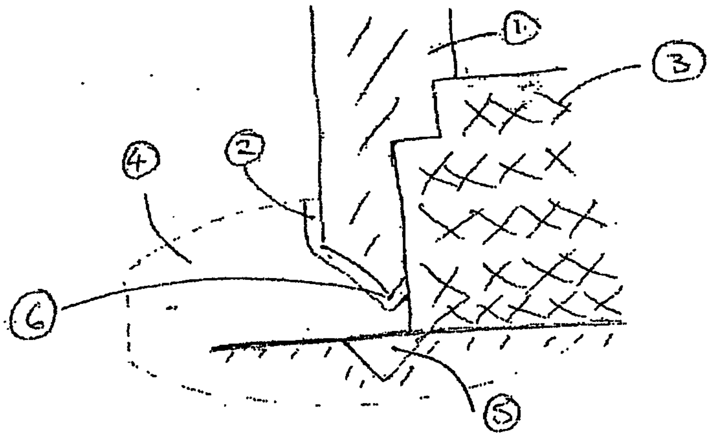

Fig 16

The VEE of the anvil (fig 16/5) is illuminated by the light emitting means (fig 16/4). The control means can determine that this is likely to be the VEE of the anvil as it detects the light through the VEE being fully enclosed by shadows (the anvil below and material above). If the stop zone around the blade (fig 16/2) is obstructed when the VEE of the anvil is detected then the blade is stopped a safe distance from the material and the operator required to confirm the obstruction is safe (this is usually done by releasing and re-asserting the approach switch).

After the operator has confirmed this as being safe, the controller permits further approaching of the blade. The blade is not stopped again in this approach stroke unless the controller detects another image that can be interpreted as a VEE of the anvil.

Operation without an external blade position detector still permits uniterrupted operation when the controller can determine the operator is safe.

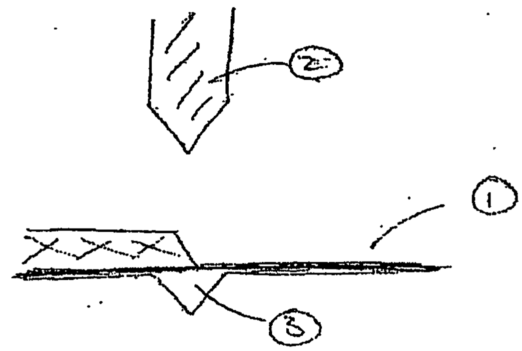

Fig 17.

Lets say the rear of a press is mechanically guarded at the rear and the front of the blade is not obstructed (fig 17/1). The control means uses the VEE of the anvil (fig 17/3) to determine where the botom of the material is. The blade (fig 17/2) would travel without stopping at the material (fig 17/1) as the material in front of the blade is low enough for the control means to determine a safe state exists.

To maintain a safe device, old SHADOW MAPs are discarded from the SHADOW STACK if they are not redetected during normal operation within a prescribed timeout period.

The control means has three methods to reduce false triggering:

- Shadow expansion - the edges of the shadow is expanded by sufficient pixels to allow for vibration and other inaccuracies in the sensing process.
- Ignoring the shadows while the blade is stopping - due to high decelerations deflecting the light emitting and receiving means while the press is stopping, the SHADOW MAP is NOT updated during this period.
- Ignore back gauge action - the control means ignores the action of the press back gauge. The shape and possible positions of the back gauge are pre-configured into the safety device when the safety device is first commissioned.

Inventive steps

Inventive or innovative steps involved in this new product include but are not limited to:

- Use of large area parallel ray light emitting means (fig 5) to illuminate objects in a similar fashion whether they are close to or far from the light emitting means.
- Use of large area parallel ray receiving means (fig 6) to both detect objects in a similar fashion whether they are close to or far from the receiving means and to reduce interference from ambient light.
- Use of a parallel ray light receiving means as this ensure ambient light does not swamp the light signal received from the light emitting means.
- Use of the same off-axis parabolic reflector arrangements in both the light emitting and light receiving means, thus reducing the manufacturing cost.
- Using a camera – actually a charge coupled device (CCD) to detect the shapes of light obstructions between the light emitting and receiving means.
- Illuminating part of the CCD (fig 9) so that it can operate at higher than the normal frame rate.
- Modulating the ON time or intensity of the laser to permit the control means to ensure the receiving means is detecting light from the light emitting means.
- Use of a shadow map that stores valid shadow patterns versus the position of the blade, this permits the control means to react to new states, warning the operator of potential danger.
- Possible operation without needing a blade position detector (opto encoder). This is acheived by using the light projected down the VEE of the anvil as a known reference position. Where either the material being bent or a light mask placed onto the anvil form the datum edge for the reference position.
- Cross checking the blade position against the perceived anvil position.
- Use of a computing means to analyse the shadow pattern (fig 17) and conditionally stop the press if a dangerous state is detected.
- Use of a SHADOW MAP to determine when objects have moved.
- Use of a SHADOW MAP stack to reduce machine configurations when sets of different shapes are repeatedly bent.
- Placing a shadow mask over the light emitting means so the control device can check the alignment of the light emitting means.
- Sensing a slight divergence of received light rays so the control means can determine the correct alignment for the light receiving means.
- Strobing of the light emitting means to reduce motion blurring effects.
- Use of a very small pinhole aperture in the light receiving means.

Although the following changes may reduce the effectiveness of the device, these changes should not allow a competitor into the market.

- A matrix of focussed light emitting means could be used instead of a single light emitting means.

- A matrix of discrete sensors could be used in place of the CCD.

- This device could be re-designed for smaller machines where it may not be necessary for both the light emitting and light receiving means to emit or detect predominantly parallel rays of light.

- Although very difficult, a sweet spot pin photodiode could be used with a matrix of light emitting means being pulsed so as to produce a picture. In this method, the lights in the matrix could be pulsed one after the other in a scanning arrangement so that the pin photodiode turns on when a parallel ray of light is received from the matrix and stays off when an obstruction casts a shadow.

- Although even more difficult, a row of sweet spot pin photodiodes could be used and places behind an optical slit. Many wide beam lasers could then be flashed sequentially so as to produce a picture in a similar fashion to that mentioned in the previous point.

- Addition of SHADOW MAPS (modified to be say trip points) onto existing safety devices as described under the heading 'Light beam on moving member'. The addition of a SHADOW MAP to these devices would enable them to trip on the first stroke then ignore known obstructions on subsequent strokes.

NOTE1: With minor changes, the light emitting and receiving means could just as easily be mounted onto the anvil instead of the blade.

NOTE2: Other corrective optics are also available and include but are not limited to:

- A combination of matched diverging and converging lenses.
- Aspheric (not spherical) lenses.
- Gradient index lenses.
- Doublet lenses.
- Cavity mirrors.

NOTE3: Other light emitting devices are also available and include but are not limited to:

- Light emitting diodes (LEDs and OLEDs).
- Xenon flash tubes.
- Plasma screen.
- Filament lamps – a polarising screen must be used in order to flash the light from these though.
- HeNe lasers.

NOTE4: Other methods are available for detecting safe states are also available and include but are not limited to:

- Valid positions or zones for foreign objects.
- Predefined danger zones.

Possible future refinements include but are not limited to:

- For shorter presses, to replace the light emitting means with a vertical large area light emitting means, this would be much like a fluorescent light that you would see in the ceiling of a office with roof placed on its side at the light emitting end of the safety device. This device may have a predetermined pattern on it so the light receiving means could determine its position.
- Addition of a quartz deflection device in front of the transmitting or receiving means to correct for vibration.
- Improve the controller means by including analysis of the bending of the material. This may be able to reduce the likelihood of finger entrapment.
- Add a vernier adjustment for the direction of the light emitting means and either adjust the direction automatically or show lights on the device to help an operator align the light emitting means.
- Add a vernier adjustment for the direction of the light receiving means and either adjust the direction automatically or show lights on the device to help an operator align the light receiving means.